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REPORT

Specification of the timing stabilities of broadcast monochrome and PAL colour television signals

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**SPECIFICATION OF THE TIMING STABILITIES OF BROADCAST
MONOCHROME AND PAL COLOUR TELEVISION SIGNALS**

**J.R. Chew, B.Sc., (Eng.), M.I.E.E.
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Summary

The subjective effects of timing instabilities in television signals have been studied. In Part 1 of the Report, movements of the monochrome picture due to fairly large timing errors are considered, and the effects of the performance of the receiver horizontal-synchronising circuits are explored. For the simple case in which the timing error is a simple periodic function, a specification is derived for the allowable error for barely perceptible impairment with the worst-case receiver synchronising circuits expected.

For the more usual case in which multiple timing errors occur, an objective measure of the subjective impairment cannot readily be found. To facilitate the assessment of equipment, such as video tape recorders, details are given of a simulator providing horizontal synchronising-circuit performances equivalent to worst-case and typical receivers.

In Part 2 of the Report, picture impairments due to rather small timing errors of the order of a few nanoseconds are considered. These errors produce perturbations in the phase of the colour subcarrier and cause patterns of varying saturation in the displayed picture. During the course of work aimed at assessing the visibility of these impairments, a property of PAL decoding came to light which has a considerable effect on the visibility of the patterning. This effect is described in this Report together with its effect in tightening the specification of the timing stability of broadcast PAL colour-television signals. The results of subjective tests are described and a target specification is given for the timing errors allowable if there is to be no visible impairment. The outputs of existing high-quality video tape recorders and analogue field-store standards converters do not fully meet this stringent requirement.

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Head of Research Department

Research Department, Engineering Division,
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1. General Introduction

A television signal should provide a uniform flow of picture information punctuated by evenly spaced synchronising signals.

The effect of timing perturbations about the correct mean value in television signals is to introduce horizontal displacements of parts of the television display, together with variations of the phase of the PAL chrominance sub-carrier and hence variations in the saturation of the displayed colour. The timing instability permissible if the impairments to the picture are to be maintained within acceptable limits is an aspect of television signal specification which has not been fully covered hitherto.

The importance of determining a specification arose when the use of helical-scan video tape recorders, in which such timing perturbations are a prevalent short-coming, were considered as means for providing some television studios with monochrome video tape facilities at an acceptable cost, for programmes of local interest, and, for this reason in particular, a method of assessing the acceptability of their timing errors was required. Further, helical-scan colour video tape recorders are also now being assessed. Because timing perturbations on monochrome and colour television signals cause differing effects, this Report has been divided into two sections: Part 1 deals with the relatively large timing errors applicable to monochrome signals, and in Part 2, the effects of perturbations of only a few nanoseconds on colour signals are discussed.

2. Introduction to Part 1

This Section of the Report deals with the effects of timing perturbations on monochrome signals, which can amount to some tens of microseconds peak-to-peak. The instabilities may occur in the timing of the synchronising pulses, or in the timing of the picture signals, or both. When synchronising pulses are affected, the performance of the horizontal synchronising circuits in domestic television receivers has an important effect upon the positional stability of the displayed picture.

Subjective tests have been carried out to determine the tolerable levels of positional instability of the display and, in co-operation with BREMA,* measurements have been made of the flywheel-synchronising performances of a number of domestic receivers.

*British Radio Equipment Manufacturers Association

3. Subjective tests using monochrome television pictures

The subjective effects of introducing known horizontal displacements of the whole or parts of both still and moving pictures were measured. In the tests the timing of the video signal was perturbed by known amounts and the picture was displayed on a picture monitor separately synchronised by stable synchronising pulses, and three forms of perturbing function, namely sine-waves, square-waves, and random noise were used initially. The observers were found to be somewhat more tolerant to random perturbations but, in general, for a given peak-to-peak value, the waveshape was not found to be important; the peak-to-peak value of the random noise was taken as 18 dB above the measured r.m.s. value. The detailed tests were carried out using sinusoidal timing perturbations, and the amounts of displacement (in equivalent ns) causing picture impairments corresponding to EBU grades 1½ and 3½ (on the six-point scale) at various frequencies are shown in Fig. 1. Viewing conditions conforming to a CCIR draft Recommendations (see Doc. 11/1009) were provided for the above tests.**

It will be seen that still pictures provide the more stringent conditions. The measurement frequencies were all chosen to cause slow horizontal movements of the whole or part of the displayed picture, resulting in the impairment having maximum visibility. When, conversely, the measurement frequencies were chosen to be integer multiples of field-frequency (50 Hz), no horizontal movement occurred and the impairment was less noticeable; Fig. 2 is a graph of similar form to Fig. 1 and the tops of the vertical lines in Fig. 2 show the peak-to-peak displacements, at these multiples of field frequency, which caused impairments graded as 1½ on the EBU impairment scale. The tolerance to disturbance at multiples of field frequency diminishes rapidly as the multiple increases, it appears that, where the vertical 'spatial' wavelength of the disturbing sinusoid is small, the eye can more easily detect static displacements of portions of a vertical edge. The corresponding curve, for frequencies with maximum visibility, from Fig. 1 is replotted for comparison (this is the solid line), also shown, as a dotted line, is a simplified version of the same curve. Both the vertical lines and the simplified curve are used later in specifying the maximum disturbance at a single frequency which may be permitted due to timing instability of a broadcast signal.

**Monitor white luminance: 75 Cd/m²
Contrast ratio: 100:1
Background ambient illumination: 7.5 Cd/m²
Viewing distance: six times picture height

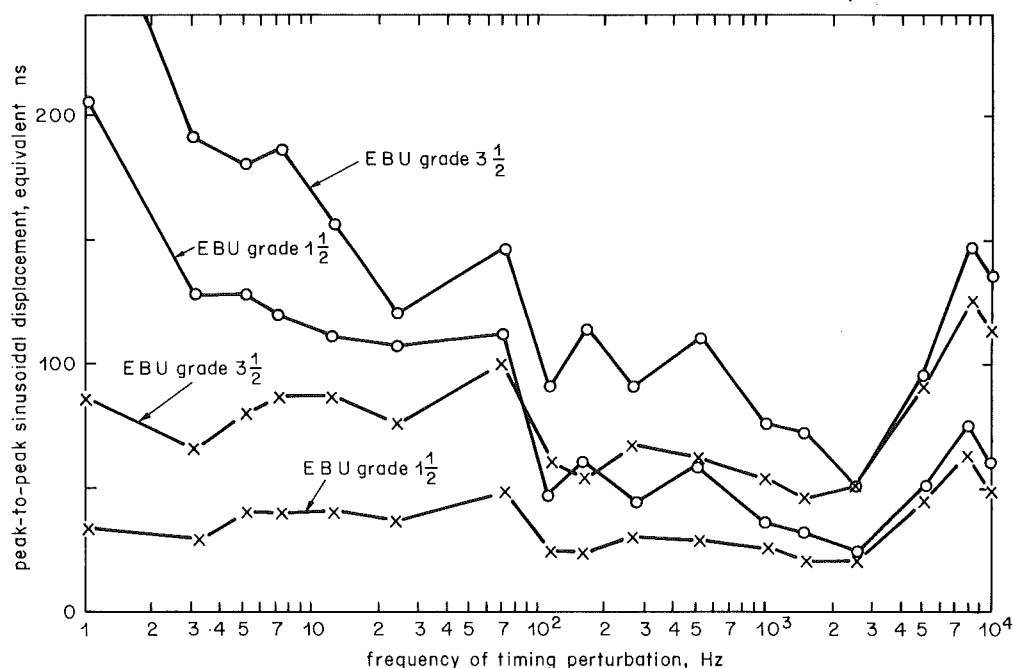


Fig. 1 - 625/50 monochrome television horizontal displacement for given E.B.U. impairment grades
 —O— moving pictures —X— still pictures

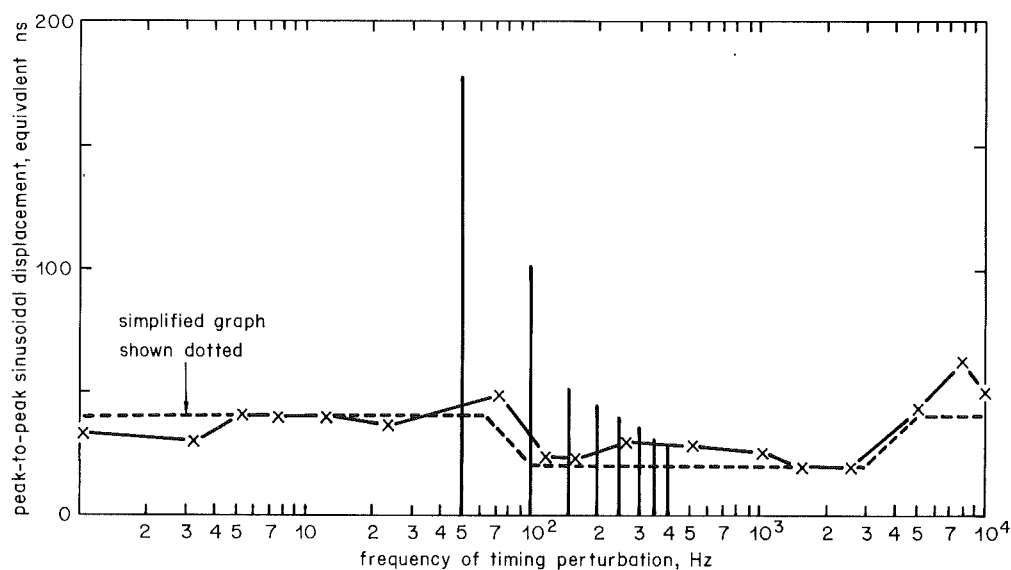


Fig. 2 - 625/50 monochrome television horizontal displacement for E.B.U. impairment grade 1 1/2

4. Effects of receiver flywheel performance on positional errors due to signal timing instabilities

Flywheel synchronising circuits are incorporated in most modern television receivers, with the object of reducing the horizontal picture-disturbances caused by noisy (fringe-area) synchronising signals. These circuits average or integrate the timings of many successive line-synchronising pulses, thus smoothing out the line-to-line

timing disturbances caused by the noise. The same property causes the circuits to respond in a sluggish manner to timing perturbations.

Fig. 3 shows the general shape of the relevant characteristics of a flywheel synchronising circuit.¹ The ordinate is the normalised phase-error, defined as the difference in effective phase between the input and output of the fly-wheel synchronising unit, divided by the phase disturbance

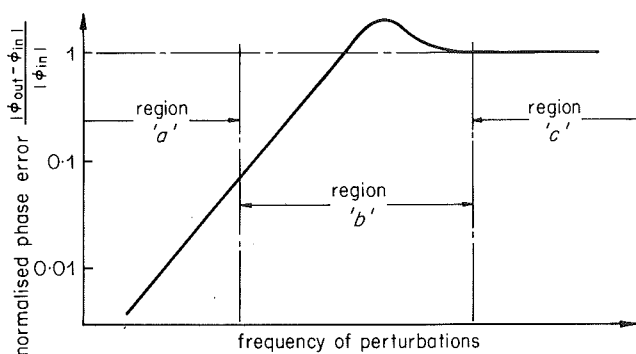


Fig. 3 - General shape of flywheel phase error curve

at the input due to a phase (or timing) error that is varying sinusoidally with time. In Fig. 3, the normalised error is plotted as a function of the frequency at which the input phase is disturbed. The normalised phase-error indicates the ratio of the actual disturbance appearing on the display to that which would be observed if the display were synchronised by a perfect set of synchronising pulses, the picture signals suffering sinusoidal timing variations equal to those of the input signal to the flywheel at any frequency. In the low-frequency region 'a' of the curve, the visible disturbance is small because the flywheel follows the input disturbance closely. In the high frequency region 'c', the flywheel time-constant is too great to permit the receiver timebase to follow timing disturbances of the input synchronising signals, so that the normalised phase error is unity and the disturbances are displayed again as if the display were separately synchronised by undisturbed pulses.

In the middle-frequency region 'b', however, depending upon the characteristics of the flywheel servo, the

normalised phase-error may well be greater than unity and the timing disturbances of the input synchronising signals will then be effectively magnified. Receiver flywheel servos with long time-constants and/or low damping factors have been found to be the worst cases, as far as input signal timing-instabilities are concerned.

Objective measurements were made of the performances, in respect of output-timing error versus input-timing perturbation-frequency, of the flywheel horizontal-synchronising circuits of a number of domestic television receivers. The receivers chosen for tests were supplied by members of BREMA, and included all those models, with flywheel circuits having long time-constants, which are or will be used in Britain in significant numbers.

The performances of two 'worst-case' receivers and that of a typical receiver are shown in Fig. 4. Also shown in Fig. 4, is a dotted set of straight lines representing limits within which the flywheel performances of future designs of receiver may be expected to fall. These proposed limits were agreed as likely (though not as mandatory) by members of BREMA.

Thus, in attempting to limit the amount of positional instability appearing on the viewer's picture, it is necessary to specify the timing stability of the received signal taking into account the performance of the receiver flywheel circuits.

5. Attempt to propose a monochrome broadcast signal specification

When the disturbance is a single sinusoid, the allowable magnitude has been assumed to be that which produces an impairment of grade 1½ (Fig. 2) after allowing for the worst receiver that may be expected. The result of this combination of subjective effects (Fig. 2) and receiver

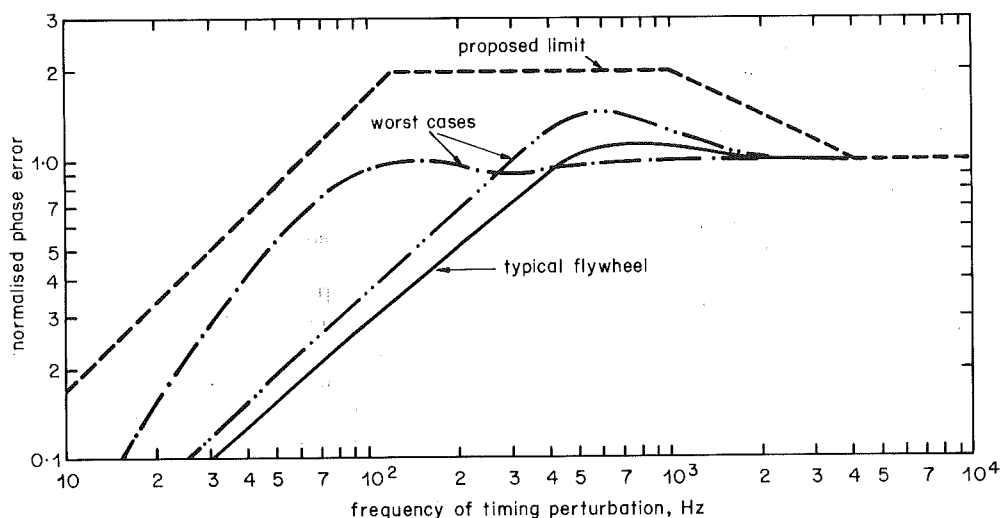


Fig. 4 - Performance of flywheel synchronising circuits in British television receivers

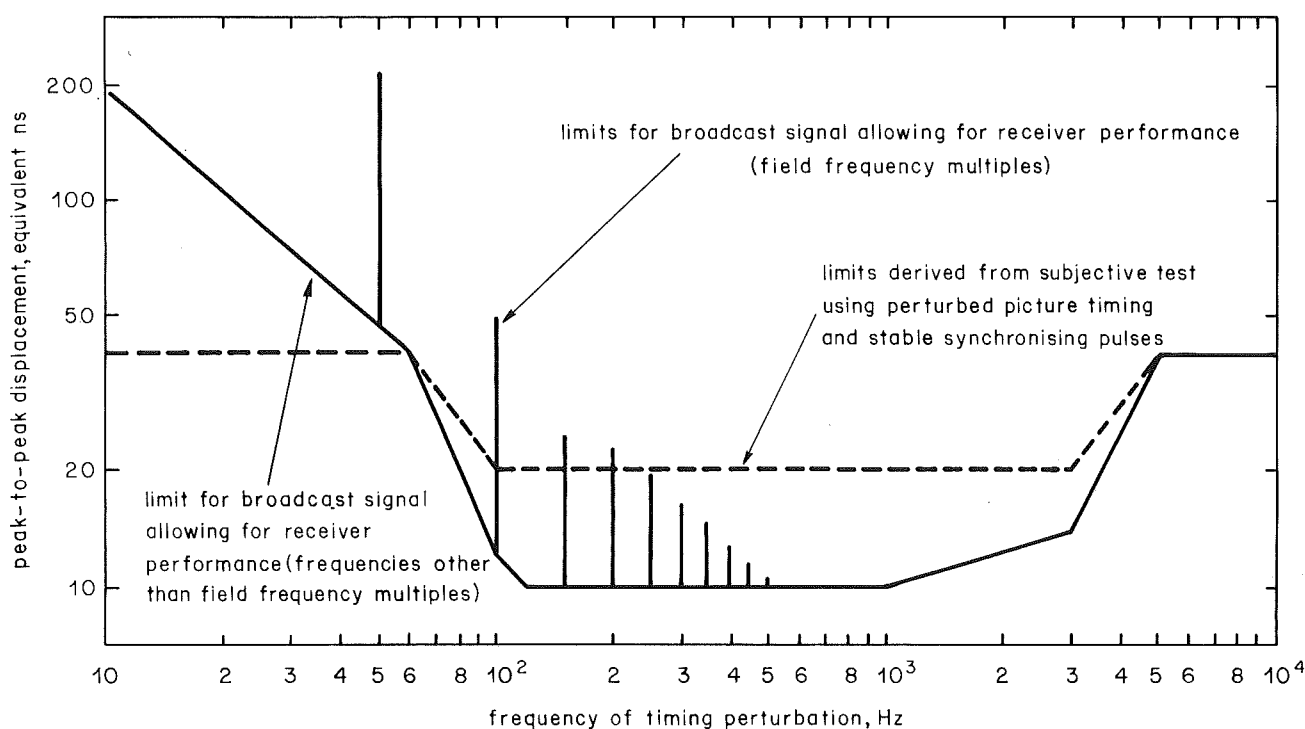


Fig. 5 - 625/50 monochrome television timing disturbance limits for broadcast signal allowing for effect of worst case receiver flywheel

performances (Fig. 4) is shown in Fig. 5; the tops of the vertical lines indicate, as before, the values of acceptable disturbance at multiples of field-frequency.

When several sinusoidal perturbations are simultaneously present, however, a difficulty arises in estimating the total subjective effect of a number of individual subjective effects. Although the problem can be approached by first normalising the disturbance at each frequency in terms of the maximum allowable at that frequency, addition of the normalised values yields an incontestable answer only in the obvious cases where either the sum of the normalised figures is less than unity or any one of the normalised values is greater than unity. The situation is further complicated when, as is often the case with video tape replay, the disturbances are due to a mixture of discrete frequency and random components. No satisfactory method has yet been evolved for deriving an objective figure of subjective acceptability in the latter situation.

Lack of a trustworthy objective criterion thus forces the use of subjective tests finally to determine the adequacy of the performance of a system or piece of apparatus. To ease the burden of such testing and to eliminate the need to use a number of receivers for each test, a receiver-flywheel simulator has been developed.

6. Receiver flywheel simulator

This apparatus has been designed to separate the synchronising pulses from a composite video signal, and from these pulses to provide, using a flywheel circuit, output pulses suitable for the synchronising-pulse input of a hard-locked television picture monitor. Fig. 6 shows the block diagram of the simulator which consists of two units, a sync-switching unit to provide gating facilities together with an output of field synchronising pulses, and a flywheel unit to provide processed line-synchronising pulses. The flywheel unit applies line pulses derived from the source under test to a phase-locked oscillator. The characteristics of the oscillator servo loop can be altered by changing the filter constants and a switch is provided for this purpose.

The flywheel characteristics of the simulator have been adjusted to simulate the characteristics which could occur in a receiver conforming to the limit curve of Fig. 4. In order to provide three worst-case performance characteristics as shown in Fig. 7 because it was not practicable to design a flywheel simulator that could approach the limit throughout the required frequency range. If when testing, for example, a video tape recorder it is found that a satisfactory performance is obtained under all three conditions it may be concluded that a satisfactory performance will be obtained with any domestic receiver likely to be encountered. The simulator is provided also

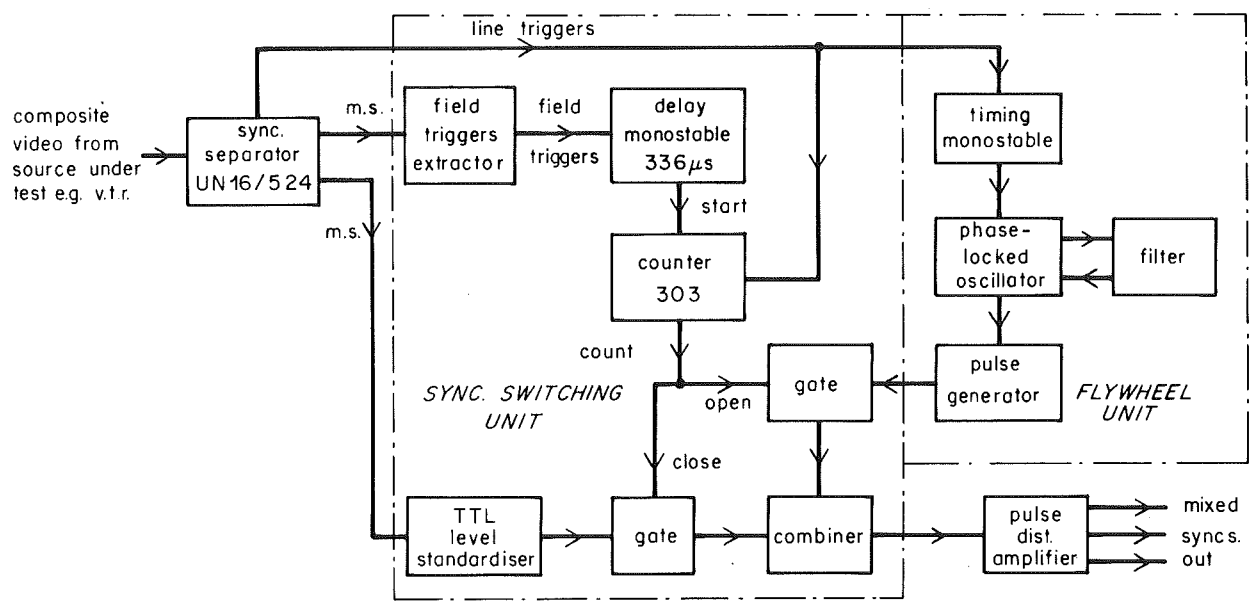


Fig. 6 - Receiver flywheel simulator for use with hard-locked monitor

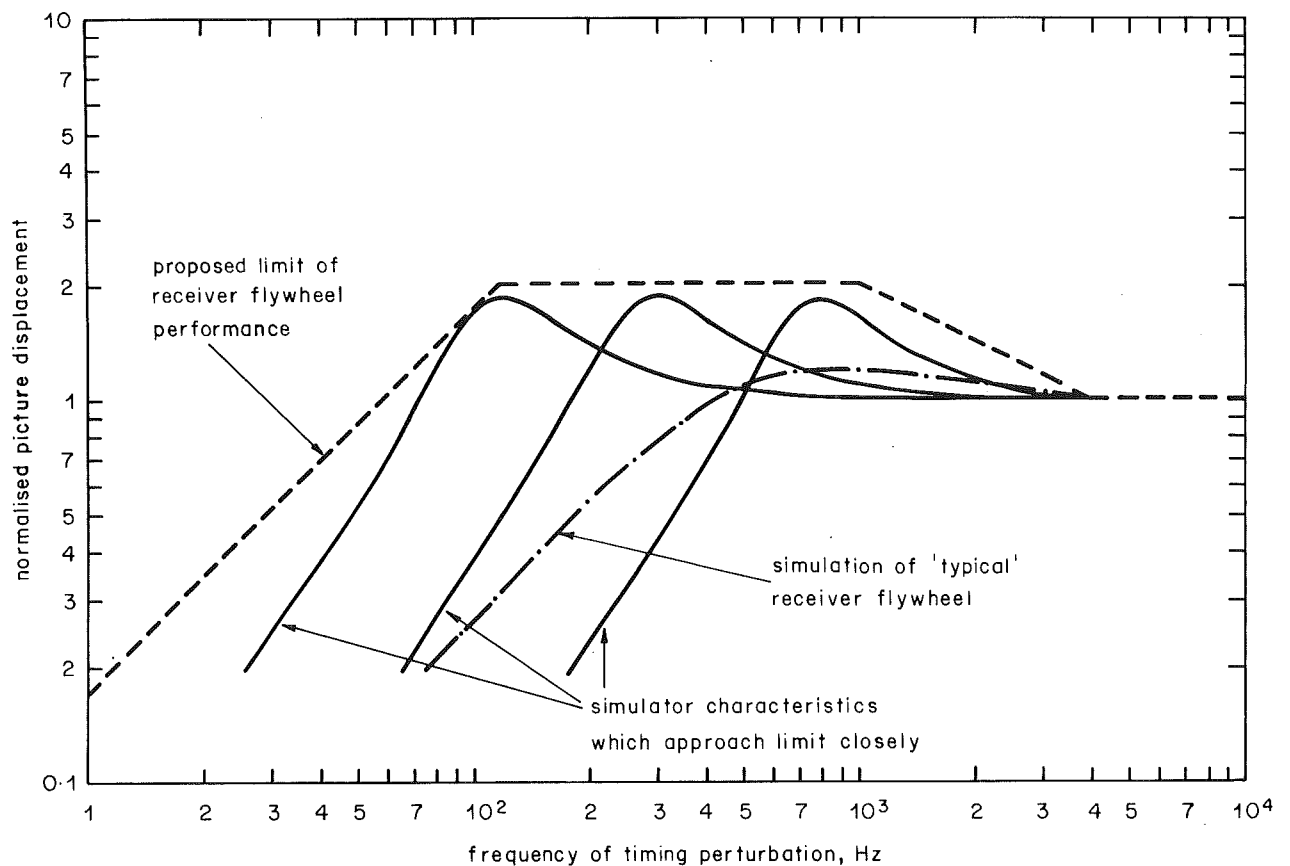


Fig. 7 - Performance curves of the flywheel simulator

with a fourth characteristic which closely approximates the performance of the typical television receiver shown in Fig. 4, and this may be regarded as an indication of the performance to be expected in most cases.

7. Conclusions to Part 1

It has been shown that where timing perturbations of one or two hundred nanoseconds are transmitted, both the frequency of perturbation and the performance of the horizontal synchronising circuit in the receiver have an important bearing on the visibility of the resulting sideways movement of the displayed picture. It has been found that there is wide variation in the performance of the line-synchronising circuits in domestic television receivers and, in consequence, the visibility of timing perturbations for different receivers varies widely. A large number of receivers were tested and the recommended timing specification as laid down in Fig. 5 takes account of the performance of the worst-case receiver.

No satisfactory combination law was obtained, where the subjective effects of several frequencies of perturbation simultaneously present could be derived from objective measurements, but a flywheel-simulator has been made and recommendations have been made to manufacturers on receiver line flywheel performance.

8. Introduction to Part 2

The purpose of this Section of the Report is to discuss the specification of the timing-stability of broadcast PAL colour-television signals. This part is not concerned with the timing perturbations that are sufficiently large to cause visible sideways movements of the displayed television picture, but rather with perturbations so small that, while the colour picture appears geometrically steady, it yet contains errors which can cause severe impairments to the reproduction of coloured areas which are due to phase-perturbations in the chrominance signal. During the course of this work, a property of PAL signal decoding came to light which hitherto had been not fully appreciated; this property places one of the most significant constraints upon the final timing-stability specification.

Subjective tests have been carried out to determine the tolerable level of timing perturbations for various forms of perturbation, and a realistic broadcast specification is suggested. The specification is of assistance not only in specifying video tape-recorder timing-stability but the results emphasise the importance of maintaining a close tolerance on the specification of mean burst-phase in the general broadcast signal.

9. Timing perturbations of broadcast PAL television signals

9.1 General

Many broadcast colour television signals are subject to small timing perturbations, the nature of which depends on the equipment involved. For instance, if a live programme is being transmitted from a studio, using studio cameras, then the short-term timing perturbations of the chrominance signal are those due to stability of the colour subcarrier generator; the perturbations would typically be less than 0.1 ns peak-to-peak. On the other hand, the equipment used often includes a video tape recorder, or sometimes a field-store standards converter, and in such cases the perturbations would typically be 6 ns peak-to-peak.

9.2 Timing perturbations at the output of video tape machines

The output signals from high-quality video tape recorders (which include timing-correctors) contain small timing perturbations of several nanoseconds peak-to-peak about the correct mean value. The perturbations are caused by the mechanical properties of the tape, and the tape and head transport systems; on replay, the timing-correctors attempt to remove the perturbations using synchronising pulses and colour-burst signals derived from the recorded signal, by comparing them with appropriate reference signals, and then applying the derived control signal to circuits that correct the timing errors. The accuracy of this process is limited, however, by the accuracy with which the phase of the colour-burst can be measured; this in turn depends on the level of noise and moiré interference present on the replayed signal.

Thus, the magnitude of the perturbations depends upon the particular machine in use, the properties of the tape and the number of record/replay processes involved in making the particular video tape recording that is being replayed. In a practical case, using a carefully aligned high-quality quadruplex machine, the timing errors may correspond to a peak-to-peak error of 10 degrees of colour subcarrier phase. Measurements have shown that the frequencies of the timing perturbations are concentrated in the lower part of the audio frequency spectrum.

10. The properties of PAL decoding circuits

10.1 General description of effect of perturbations on a PAL_D decoder

When a colour subcarrier phase-error occurs in the PAL system, the action of a delay-line (PAL_D) decoder is to convert this into a saturation error. Thus when timing (or chrominance-phase) perturbations occur of the type produced by a video tape recorder, they can result in fluctuations of saturation which appear on the picture as a pattern of coarse, horizontal bands that can have high visibility.

The degree of impairment caused depends to a large extent upon the alignment of the PAL_D decoding circuits. An advantage that has been claimed for PAL_D decoding is that the phase of the demodulating reference subcarrier is uncritical in normal circumstances, an error in reference-wave phase adjustment causes a reduction in the level of the demodulated colour-difference signal, according to a cosine law, which can be compensated by a chrominance gain adjustment.

However, in the presence of a static phase-error, perturbations of the signal-phase result in corresponding variations of colour-difference signal level whose magnitudes depend upon the extent of the static phase-error, approximately according to a sine law. Fig. 8 illustrates the effect. Two further points are important:-

(1) When the static-phase is correct, the colour-difference signal variations are at a minimum and a frequency-doubling effect occurs which reduces the coarseness of the low-level interfering patterns and thereby further reduces their visibility on the displayed picture.

(2) The larger output variations, which occur when the static-phase is incorrect, are further increased by the additional chrominance gain needed to compensate for the static phase error.* As a result the relationship between the variation of a signal level and static phase-error becomes a tangent law.

As a practical example, Fig. 9 illustrates the effect on a colour picture (in this case a uniform 100% saturated red field) when the signal timing was perturbed sinusoidally by 20 ns peak-to-peak, for demodulating reference-wave phase errors of 0°, 10° and 20°; the frequency of the sinusoidal perturbations was arranged to be a multiple of field frequency so as to give a stationary pattern and thus simplify photography. The visibility of the impairment was found not to be seriously affected by the choice of perturbation frequency over a fairly wide range between 100 Hz and 2000 Hz.

Table 1 gives a brief summary of the effects of this and other decoding errors that have been examined.

10.2 Effect of the frequency of timing perturbations on a PAL_D decoder

In the previous Section, the effects of timing perturbations at frequencies concentrated in the lower part of the audio frequency spectrum have been discussed; similar effects apply up to perturbation frequencies of some 3 to 4 kHz. At frequencies near to half-line frequency (7.8 kHz) a timing perturbation of opposite polarity occurs on adjacent television lines and, consequently, the PAL one-line delay in the decoder does not separate the colour-difference signals correctly. The effect is the same as if the length of the delay line were to increase and decrease alternately at a rate determined by the perturbation frequency.

*Luminance to chrominance cross-talk or 'cross-colour' is also made worse as the chrominance gain is increased, as the level of the 'cross-colour' components is unaffected by the reference subcarrier phase, but is proportional only to chrominance gain.

ency. This produces varying cross-talk between the colour-difference signals and hence varying hue-patterns on the display; however the visibility of the hue-patterns does not substantially vary for errors in subcarrier reference-phase. The subjective visibility of this form of patterning, relative to that of saturation patterning, is discussed in Section 11 of this Report.

In general, the visibility of the saturation patterning at high perturbation frequencies, which are integer multiples of line-frequency, and of hue patterning at odd multiples of half line-frequency remain constant up to about 100 kHz, and then decrease with further increase in frequency. These effects are dealt with in more detail elsewhere² and are mainly applicable to the high-frequency jitter found in p.c.m. apparatus; for the purposes of this Report, however, the low-frequency effects associated with video tape recorders are the more important.

10.3 The effect of timing perturbations on a PAL_S decoder

The effect of low-frequency perturbations on PAL_S decoding is to cause line-by-line hue and saturation errors, giving rise to 'Hanover Bar' patterning in bands or groups of lines, as determined by the perturbation frequency. At normal viewing distances the interference caused by the perturbations appears as saturation errors because of integration by the eye, and is very similar subjectively to that experienced with PAL_D decoding.

10.4 The effect of timing perturbations on a 'New-PAL' or PAL_N decoder

A PAL_N decoder processes the chrominance signals in the same way as a PAL_D decoder. The subcarrier reference phase is, however, derived directly from the chrominance signal during the active portion of each line, rather than from the mean burst-phase. Thus any low-frequency phase-perturbations of the chrominance signal equally affect the phase of the reference subcarrier used for demodulation, with the result that there is no net error between the subcarrier signal and the subcarrier reference wave and no fluctuation in saturation. Furthermore, if the reference wave has a static phase-error, perturbations still do not cause saturation fluctuations since the change in phase of the reference subcarrier follows that of the chrominance signal.

At higher frequencies of perturbation, the performance of PAL_N decoding becomes similar to that of PAL_D decoding. This occurs when the perturbing frequency is sufficiently high to cause the phase of the colour subcarrier signal to be widely different on adjacent television lines.

11. Subjective tests

11.1 General

Subjective tests were carried out to determine the degree of impairment caused by the timing perturbation of PAL colour television signals. Perturbed signals were

Table 1

Decoding Error		Effects of signal timing perturbations		Remarks
Description	Value (for example)	Effects on Picture	Corresponding Quantitative Effects for 10 ns p-p Perturbation	
(1) Error in static reference phase	10°	Saturation-patterning (Fluctuations of saturation in coarse bands) occurring in colours* other than white	5% p-p saturation fluctuations	The most important decoding error; small errors are only revealed by timing perturbations
(2) Decoding axes not in quadrature (reference-wave phase adjusted to make error symmetrical)	10°	Hue-dependent saturation-patterning OR hue-dependent hue-patterning	Up to 2½% p-p saturation-patterning OR 1½ p-p hue-error patterning.	Less serious than (1). Colours formed from predominantly one colour-difference signal suffer saturation-patterning. For colours with similar 'u' and 'v' signal levels, mainly hue-patterning occurs.
(3) Error in delay-line length	10°	Saturation-patterning in colours* other than white (Normal PAL u/v crosstalk occurs giving 'Hanover Bars')	2½% p-p saturation fluctuations	Less serious than (1)
(4) Gain Error in delay-line Adder/Subtractor	10°	Fluctuations of 'Hanover Bars' in coarse bands occurring in colours* other than white	1.6% p-p line-to-line 'u' and 'v' signal-level differences	Unimportant in an otherwise correctly aligned decoder. However, static phase-errors (as in (1)) will increase the effect somewhat.

NOTE: The values given in this table are approximate

*The visibility of the patterns depends upon the hue and saturation of the coloured area involved

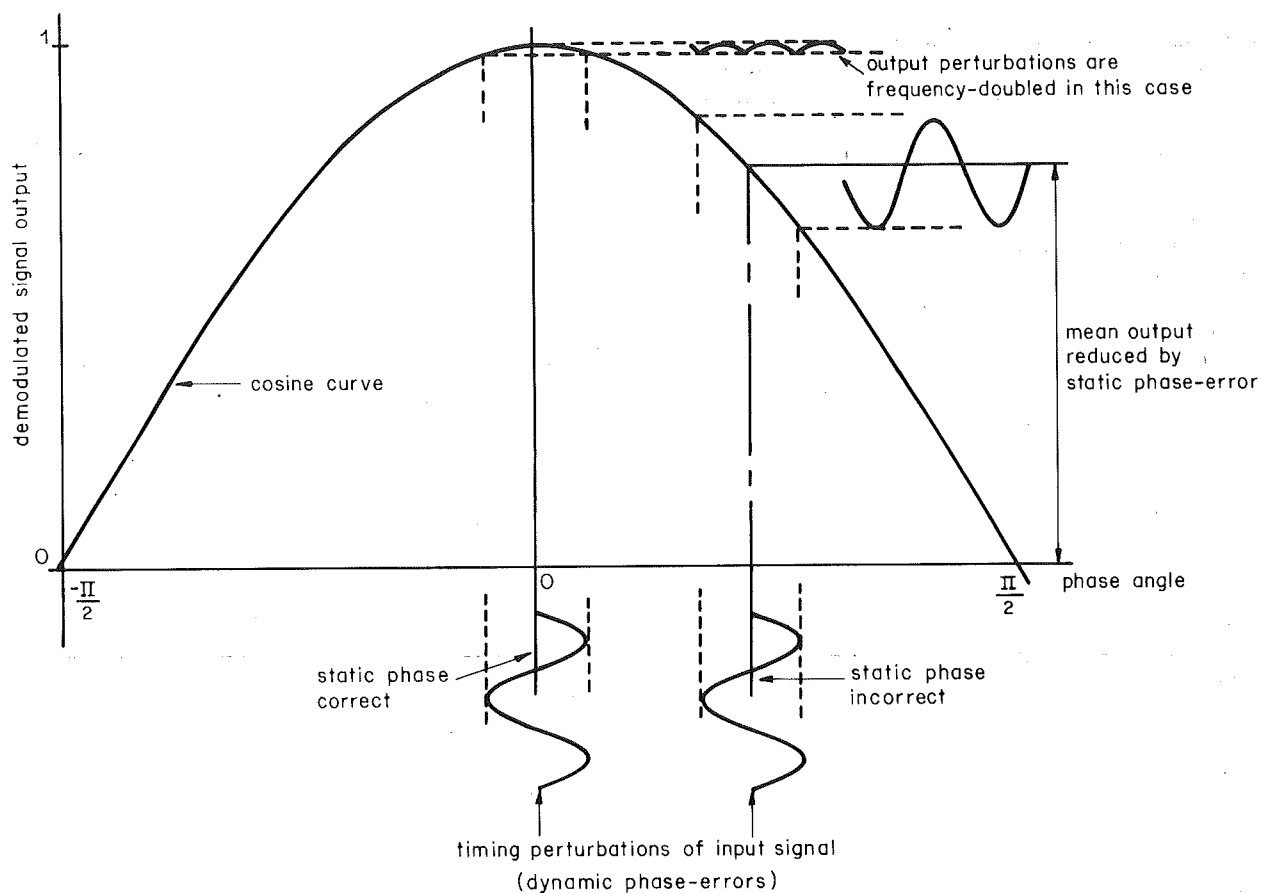


Fig. 8 - The combined effects of static and dynamic phase errors in a synchronous demodulator

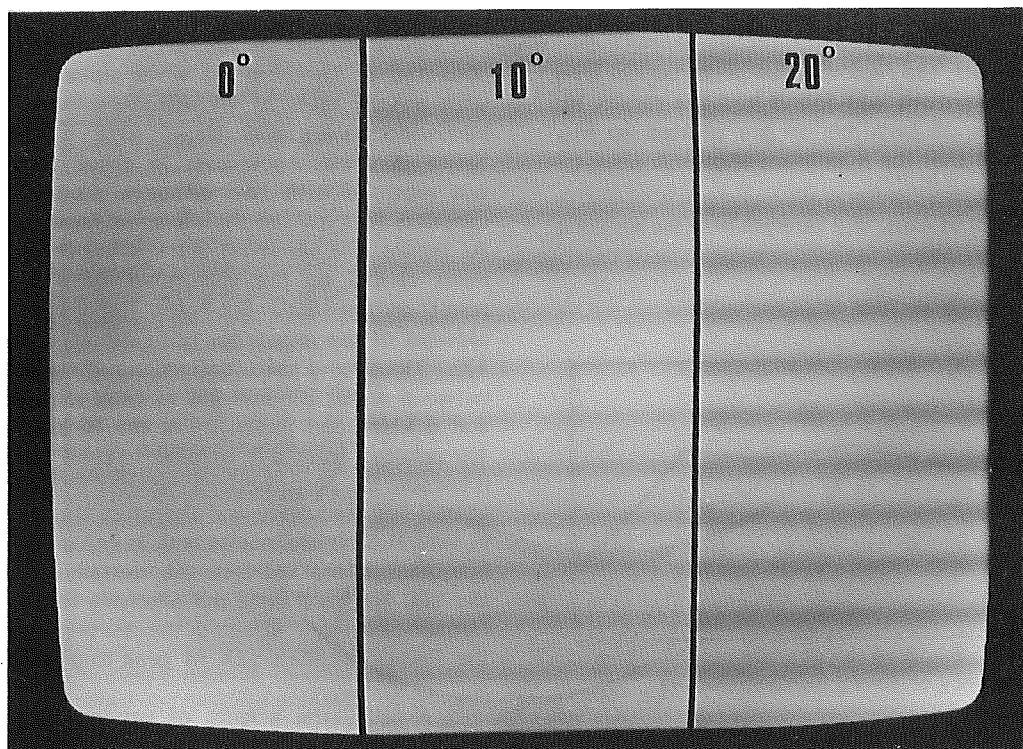


Fig. 9 - Photograph of professional PAL_D colour monitor displaying a uniform coloured field: timing of the input video signal is perturbed sinusoidally 20 ns (32 degrees subcarrier phase) peak-to-peak; static subcarrier phase as indicated

obtained artificially in the laboratory as well as practically from a high-quality video tape recorder. In these tests, recommended viewing conditions were again provided.

11.2 Tests using artificially perturbed signals

In these tests, the delay of a variable delay line was varied by means of a control waveform. The video signal to be perturbed was applied to the signal-input of the delay line and the output signal was fed to a properly-aligned PAL_D decoder; PAL_D decoding was used, because this is by far the most common form of decoder used in the UK.

The picture signals used for the tests were 95% saturated, 100% amplitude colour-bars.

In the first tests, the effects assessed were due to a sinusoidal timing perturbation in which the frequency of perturbation could be varied. Ten observers took part; they were skilled television engineers and were asked to assess the visibility of the fluctuations on the picture (for various perturbing frequencies) and to grade their observations using the EBU Six-Point Impairment Scale given in Table 2.

Table 2

EBU Six-Point Impairment Scale

1. Imperceptible
2. Just perceptible
3. Definitely perceptible but not disturbing
4. Somewhat objectionable
5. Definitely objectionable
6. Unuseable

From the results, the peak-to-peak perturbation level for Grade 1½* impairment was found and the results for differing frequencies of perturbation are plotted on Fig. 10. It can be seen that the maximum allowable peak-to-

*'Imperceptible' in 50% of cases, 'Just perceptible' in the remaining cases.

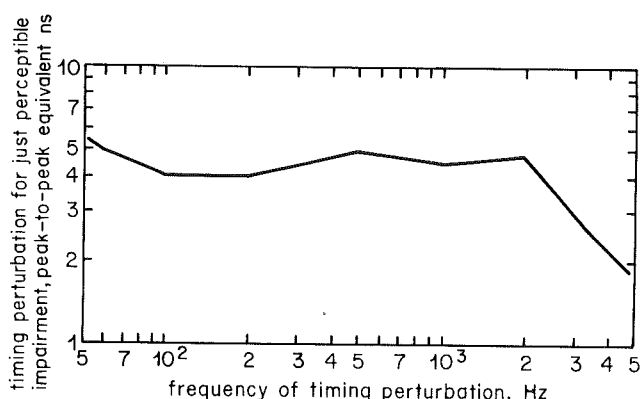


Fig. 10 - Effect of frequency of sinusoidal timing perturbation for just perceptible impairment of 95% saturated 100% amplitude colour bars

peak timing perturbation at frequencies up to about 2 kHz is 4 ns to 5 ns.

In another series of tests, using artificially perturbed video signals, the effect of very-low frequency sinusoidal timing perturbations was investigated. The purpose of this work was to determine the visibility of impairments that could arise during Genlock, Natlock or a similar operation. In such an operation while the phase of the chrominance signal can be subject to very-low-frequency timing (or phase) errors, a stable colour burst is reinserted in the video signal. Thus, the reference wave generated by a burst-locked oscillator in a PAL_D decoder fed with such a signal would not follow the low-frequency timing perturbations. This situation could arise, for example, on the output of a mixer operating in the split-screen mode with timing perturbations affecting one of the signals involved.

As a mixer was not available, the experimental arrangement was modified for this test since, otherwise, the burst-locked oscillator in the properly aligned PAL_D decoder would have followed the timing errors. To avoid this problem, the PAL_D decoder was modified to accept an external reference subcarrier, in place of the reference wave derived by the burst-locked oscillator. Apart from this one change, the equipment was the same as in the previous tests, and the visibility of impairments caused by sinusoidal timing perturbations down to 0.3 Hz was assessed. The results are shown in Fig. 11. It can be seen that apart from flicker and cancellation effects, at frequencies particularly related to field-frequency (giving the results of a fine structure), the curve shows that errors may rise up to 14 ns peak-to-peak at the lowest frequency used in the tests.

In a further series of tests the perturbing signal consisted of band-limited white noise. Low-pass filters with cut-off rates of 24 dB/octave were used and their bandwidths were 500 Hz, 1 kHz, 5 kHz and 10 kHz. Seven observers took part in these tests and each test was repeated with two different properly-aligned PAL_D decoders that utilised their internal burst-locked oscillators. As before, the observers were asked to assess the impairment caused by the perturbing signal and to grade the result on the EBU Six-Point Impairment Scale. The averages of the results for both decoders are shown in Fig. 12. The timing perturbations resulting in grade 1½ varied between about 3½ and 4½ ns peak-to-peak for the 1 kHz and 5 kHz band limits. For the 10 kHz limit a grade of 1½ resulted from a 1 ns peak-to-peak perturbation; this is because the perturbations included frequency components at half-line frequency and therefore there were hue as well as saturation impairments and, as explained in Section 10.2 hue fluctuations increase the overall impairment. With the 500 Hz band limit the relatively large amount of low-frequency energy affected the burst-locked oscillators in the PAL_D decoders (2½ ns peak-to-peak gave grade 1½).

Finally, the effects of varying the PAL_D decoder reference-subcarrier phase on the visibility of sine-wave timing-perturbations was assessed. Tests were conducted at frequencies of 100 Hz, 500 Hz and 1 kHz and Fig. 13 shows the average results obtained in these tests; in all cases the skilled observers were asked to look for just-

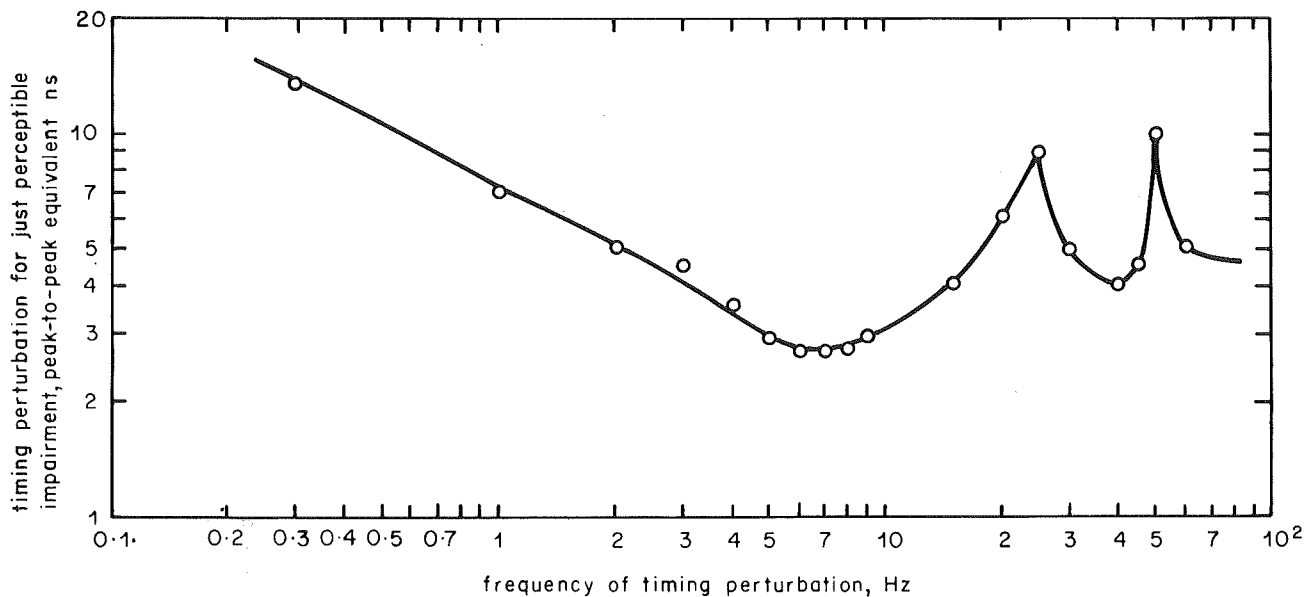


Fig. 11 - Effect of very low frequency sinusoidal timing perturbation for just perceptible impairment of 95% saturated, 100% amplitude colour bars

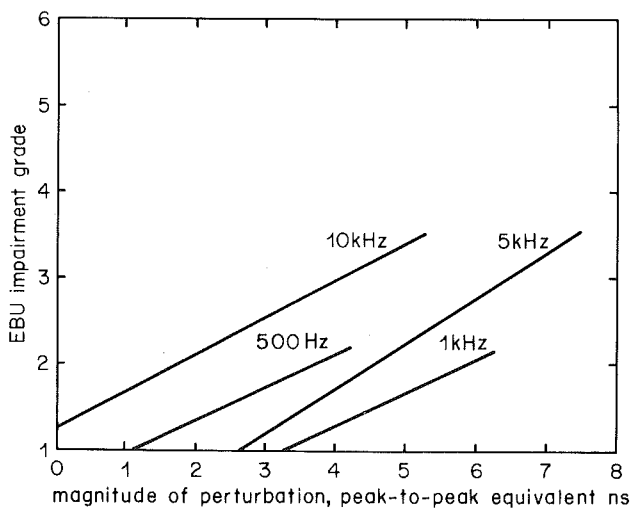


Fig. 12 - Effect on pictures of 95% colour bars, of timing perturbations whose spectra correspond to white noise with various upper-frequency limits as indicated

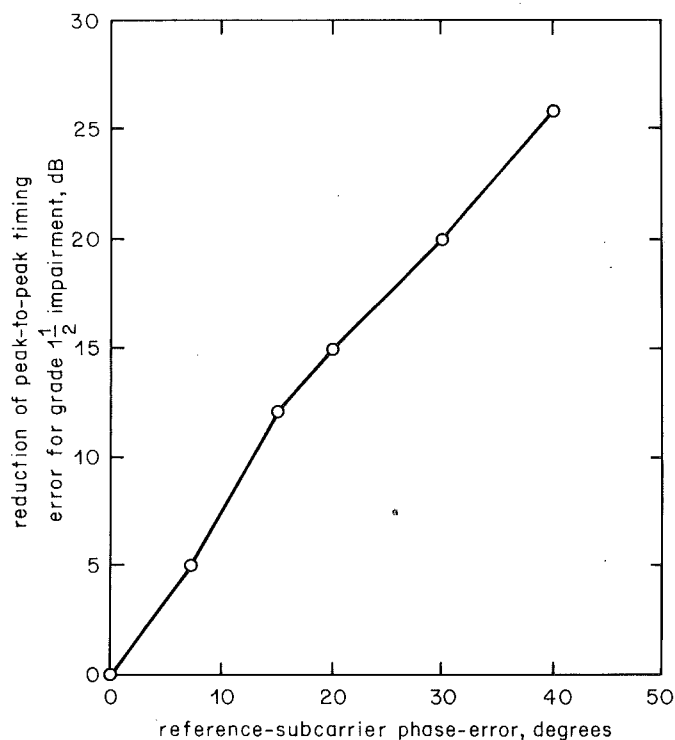


Fig. 13 - Effect of PAL_D decoder reference subcarrier phase on the visibility of impairments of sine-wave timing perturbation

perceptible impairment. It can be seen that for only 15 degrees of misalignment of subcarrier phase, the peak-to-peak timing error must be reduced by 12 dB to give the same picture impairment as that obtained with a properly-aligned decoder.

11.3 Tests using signals from a VR2000 Video Tape Recorder

Subjective tests were carried out to determine the impairments caused by errors in the decoding reference-phase of a PAL_D decoder, for the practical situation of timing perturbations caused by an Ampex VR2000 quadruplex-head video tape recorder replaying a tape previously recorded on the same machine. For all the tests, the recorder was carefully adjusted and its performance was typical of that obtained in operational service.

The picture used for the tests were 95% saturated (100% amplitude) colour bars and two colour slides; the slides were scanned in a high-quality slide scanner and each contained a reasonable sized background of plain saturated colour. Seven observers took part; they were skilled television engineers and they were again asked to assess the saturation fluctuations on the pictures (for various reference phases) and to grade their observations using the EBU Six-Point Impairment Scale given in Table 2. The PAL_D decoder used for the tests was aligned normally, with the exception that the reference-subcarrier phase was changed for each test and the chrominance-gain control adjusted to maintain correct saturation of the output picture.

Figs. 14 and 15 show the results obtained for the colour-bars and slides respectively. It can be seen that, for errors in reference-phase varying from zero to 40 degrees, the impairment varies from somewhat greater than 'just perceptible' to 'somewhat objectionable'.

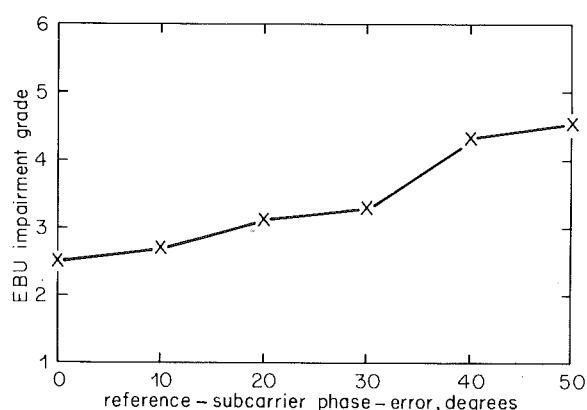


Fig. 14 - A first generation recording of 95% saturated, 100% amplitude colour bars replayed from a quadruplex-head video tape recorder. The subjective impairment for various values of PAL_D decoder reference subcarrier phase

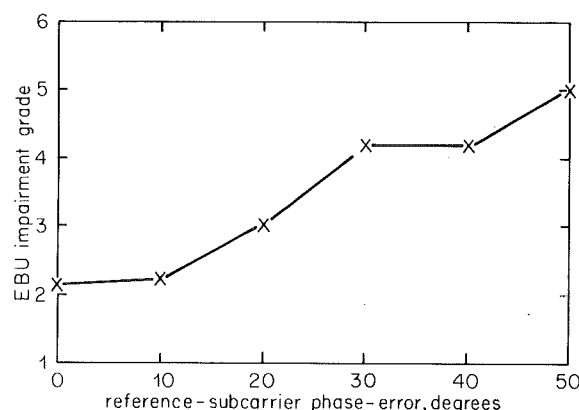


Fig. 15 - A first generation recording of colour slides with plain saturated colour background replayed from a quadruplex-head video tape recorder. The subjective impairment for various values of PAL_D decoder reference subcarrier phase

12. The specification of the broadcast signal

As a result of this work it has emerged that, in addition to specifying the time-stability of the broadcast signal, there is a new emphasis on the importance of the burst-phase. If the criterion of 'just perceptible' impairment is used, the results indicate that, for PAL decoders that are perfectly aligned, a timing tolerance of between 3½ and 4½ ns peak-to-peak must not be exceeded by the broadcaster, for low-frequency perturbations. At present, well-aligned high-quality video tape recorders do not quite meet this specification, even for first generation recordings. However, a further tightening of the specification must be made to allow for errors in the transmitted mean burst-phase (specified for system I at ± 2 degrees) and to allow for imperfect alignment of reference-subcarrier phase in commercial receivers. BREMA has been considering this latter point and tentatively suggest that, in the long-term, errors of up to ± 15 degrees might be found in the decoders in domestic colour television receivers. The effect of these further restraints is to reduce the allowable peak-to-peak broadcast perturbations by some 12 dB. The suggested final value for the allowable peak-to-peak low-frequency timing perturbations of the broadcast signal is ¾ to 1¼ ns, say 1 ns. No practical video tape recorders have a performance approaching this figure* and it must be regarded as a target specification.

13. Conclusions to Part 2

In the course of work on the specification of the timing stability of broadcast television signals it was found that the extent to which reference-subcarrier phase

*For a first-generation recording on a high-quality broadcast video tape recorder, typical perturbations of about 6 ns p-p are found.

in PAL_D decoders could be misaligned had an important bearing on the specification. This emphasises the need to maintain a tight tolerance on correct mean-burst-phase.

Broadcast video tape recorders do not at present meet the timing stability requirements.

14. References

1. MAURICE, R.D.A. *and* ROUT, E.R. 'Characteristics

of flywheel synchronising circuits in television receivers.' *Electronic Engineering* February 1962.

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